



Developments Towards US EPA 07 Using HPDI For Class 8 Tractors

Status Update For NGVTF

August 3rd 2005

Westport
INNOVATIONS INC.



Program Overview

- Funding partnership between NREL, SCAQMD, PG&E and Westport.
- Next generation technologies for LNG fuelled Class 8 tractors.
- Scope
 - ▶ Improvement in fuel economy from first generation HPDI
 - ▶ Emissions reductions of HPDI engines, targeting the 2007 1.2g NOx and 0.01g PM standards
 - ▶ EPA and CARB Certification – 2005 Ultra Low NOx and 2007 EPA
 - ▶ Development for increased reliability of fuel injection and LNG systems
 - ▶ Deployment of demonstration vehicles in customer fleets



Innovation for Our Energy Future

A national laboratory of the U.S. Department of Energy
Office of Energy Efficiency & Renewable Energy



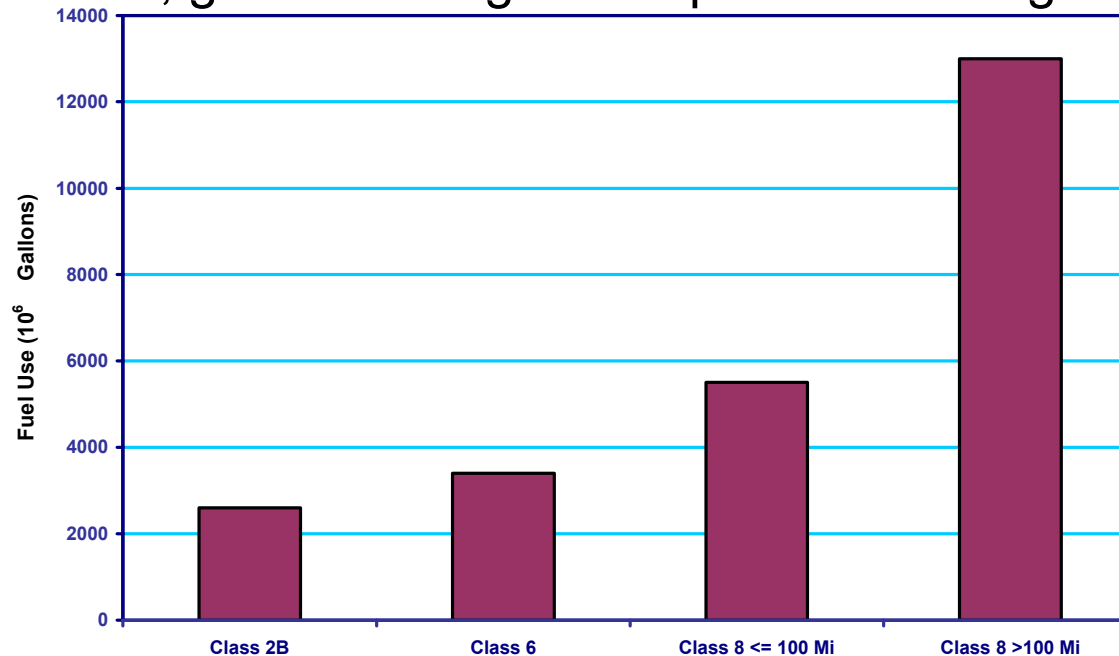
*Pacific Gas and
Electric Company®*





Background

- Class 8 tractors contribute significantly to both airborne emissions, greenhouse gas and petroleum usage.



DOE/EERE - 21st Century Truck Program – Technology Road Map – December 2001

- Pressures on petroleum use:
 - ▶ Domestic and international industrial growth
 - ▶ Engine efficiency trends with more stringent emissions standards
 - ▶ Stricter fuel formulation standards to enable emissions compliance



Maximizing Petroleum Displacement

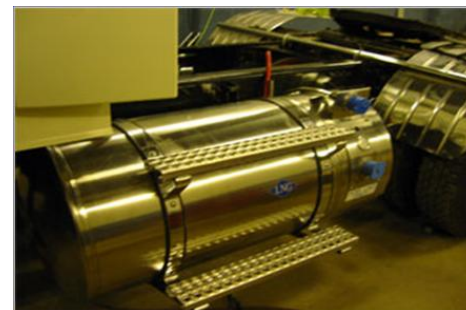
Goal	Westport Approach	Result
Replace diesel as primary fuel	Use HPDI combustion.	Typically 94-95% energy from natural gas. Max ~8% diesel under any condition.
Maximize combustion efficiency	Use HPDI combustion.	Retain or better diesel performance and efficiency.
Emissions and Aftertreatment	Avoid NOx and PM aftertreatment.	No fuel used for catalyst regeneration.
Cooling System	Minimize EGR. Use coolant for LNG vaporization.	Reduced cooling system loads and fan parasitic loads.
Fuel Handling	Improve thermal hold time of LNG tanks.	Reduced tank pressure and fuel venting requirements.



Program Approach

- Acknowledge that viable alt. fuel products for HD truck industry require similar levels of engineering dev't as diesel products
- Technology development targets long term improvements in customer economics, moving towards commercial availability:
 - ▶ Fuel economy
 - ▶ Reliability
 - ▶ Operating cost
 - ▶ Codes & Standards compliance
- Multiple industry collaborations required to complete program:

▶ NREL, PG&E, SCAQMD	– funding
▶ Norcal, BAAQMD	– fleet demonstration
▶ LACSD, SCAQMD	– fleet demonstration
▶ CARB and EPA	– certification strategy
▶ Ricardo Consulting Engineers	– transient dev't and certification test
▶ NREL	– LNG tank dynamic crash simulation
▶ Taylor Wharton	– manufacture of new LNG tanks
▶ Cummins	– engine integration support



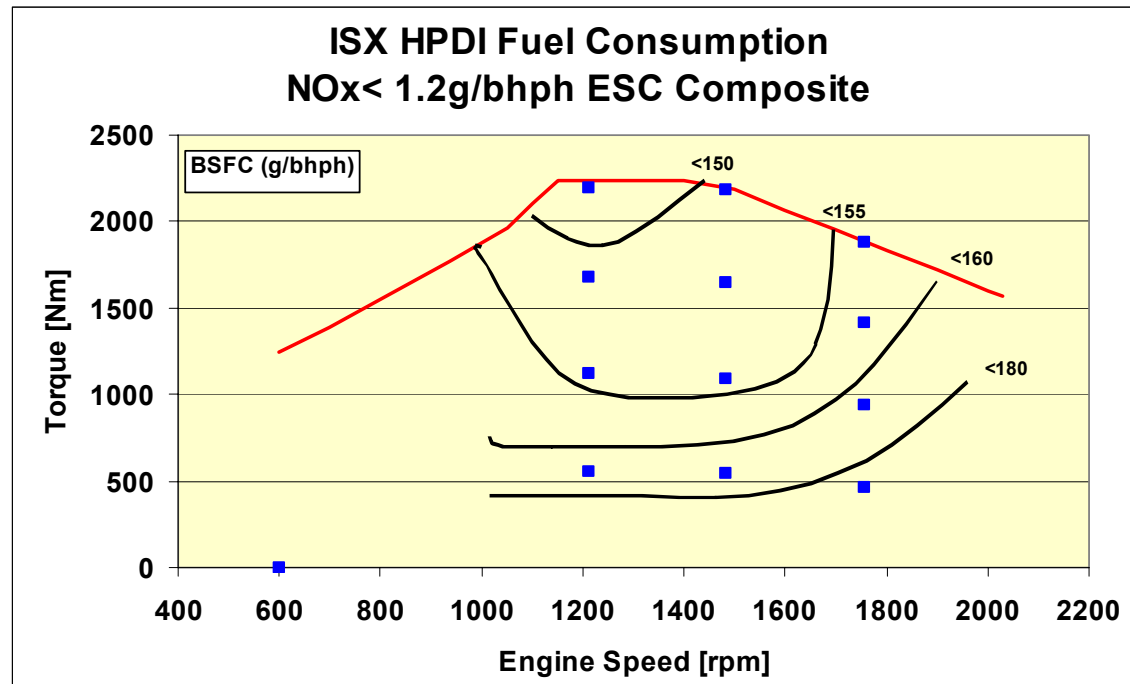


Program Status

1

- **Engine Performance – NOx, PM and Fuel Economy**

- ▶ Fuel system models and control strategies refined and implemented.
- ▶ Steady state calibration developed for $<1.2\text{g NOx}$ and $<0.01\text{g Pm}$.
- ▶ Low fuel consumption across speed and loads (up to 8% improvement from 2.2g diesel).
- ▶ Must verify under transient and in vehicle conditions.

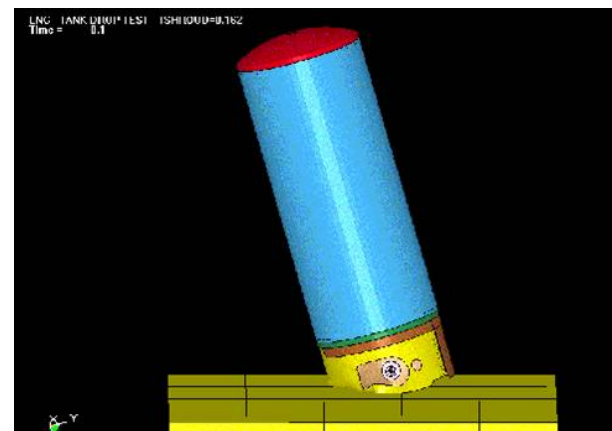
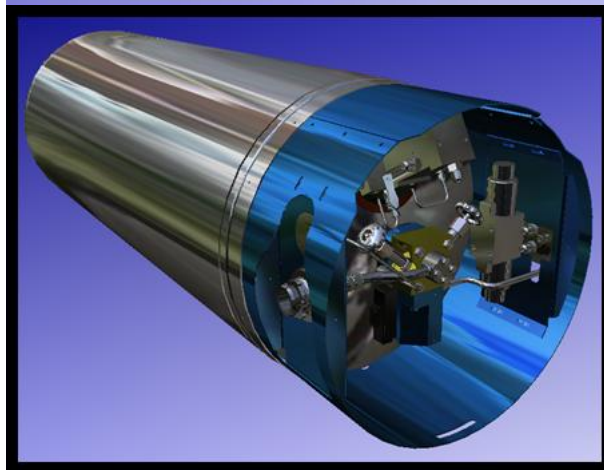
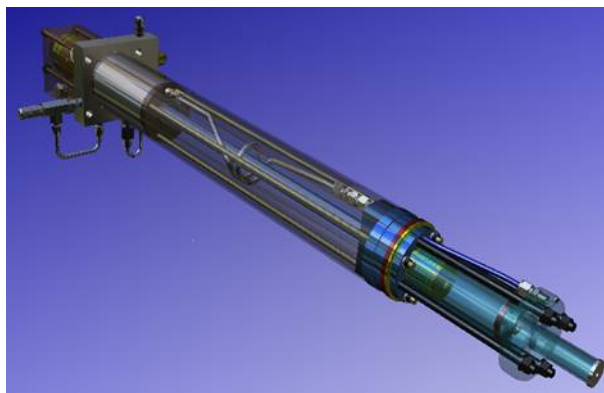




Program Status

2

- **LNG System design and development**
- Improved reliability and capacity LNG pump validated.
- Improved design LNG tank designed.
- Dynamic simulation used to revise design before destructive testing for compliance with SAE J2343.





Program Status

3

- **Reliability Development**

- Significant focus on reliability testing and design improvements using test cells, rigs and vehicles:

- ▶ Fuel system test rigs
 - 6500 engine equiv. hours
- ▶ Engine test cells
 - 1500 engine hours
- ▶ LNG pump test rigs
 - 5700 truck equiv. hours
- ▶ Engineering vehicle
 - 1200 truck hours
- ▶ 401 Corridor fleet
 - 113,000 km to date





Future Developments

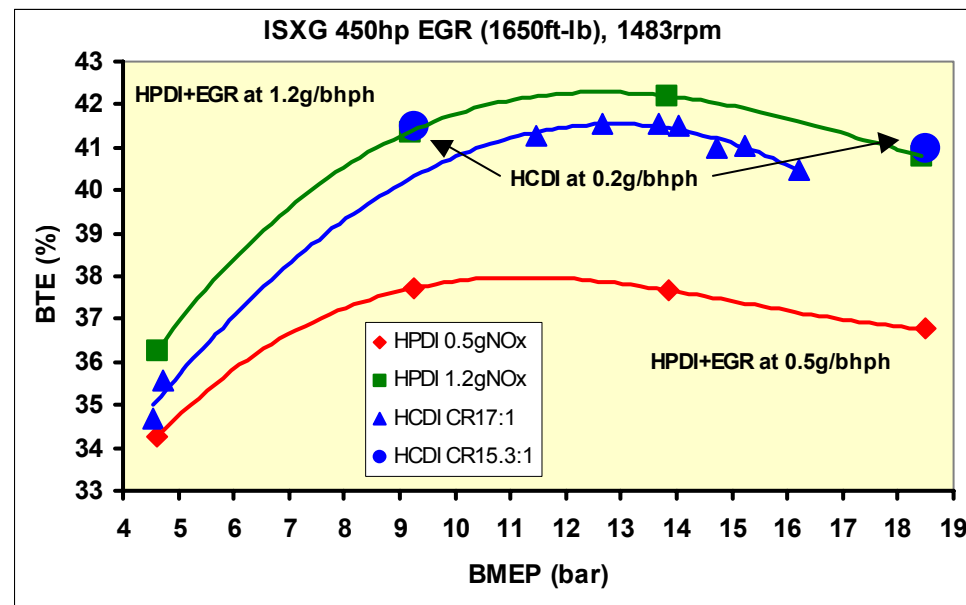
- Evaluation and development of 2010 solutions underway at Westport (0.2g NOx, 0.01g Pm).
- Aim to retain hardware commonality with 1.2g NOx solutions:
 - ▶ **Fuel injection system**
 - ▶ **LNG system**
 - ▶ **No NOx aftertreatment**
- Results to date are very encouraging using HCCI type approach:

- 0.2g NOx demonstrated across speed and load.

- Can match efficiency of 1.2g NOx system.

- Multi-cylinder ISX demonstrated to NREL and PG&E.

- Work on-going at Westport.





Next Steps

- Engine Certification testing: August '05
- EPA and CARB Exec Order: Oct '05
- NREL demo vehicles upfit: Nov '05



Conclusions

- Progress being made to :
 - ▶ Reduce emissions,
 - ▶ Enable higher ratings
 - ▶ Improved fuel efficiency
 - ▶ Increase product reliability
- Engaging wide industrial support:
 - ▶ Customers
 - ▶ Air Quality and Energy Management agencies
 - ▶ Industry product and service providers
- Westport looking for larger scale deployments in 2006 and 2007.
 - ▶ 50 to 100 trucks
 - ▶ High fuel use
 - ▶ 400 or 450 hp, 1450 or 1650 ft-lbs



Thank You

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